Eritrichum howardii (Gray) Rydberg (Howard's alpine forget-me-not) A Technical Conservation Assessment

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COVER PHOTO CREDIT

Eritrichum howardii (Howard's alpine forget-me-not). Photograph by Jan Hjalmarsson of Montana plant life. Used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ERITRICHUM HOWARDII*

Status

Eritrichum howardii (Howard's alpine forget-me-not) is a mat-forming species tending to occur on calcareous soils in open, sparsely vegetated sites. It is discontinuously distributed across Wyoming and Montana, occupying islands of suitable habitat in the mountains and foothills. Reports of occurrences in Washington and Idaho have not been verified and are probably erroneous.

Within the states of USDA Forest Service (USFS) Region 2, the Wyoming Natural Diversity Database (WYNND) reports eight occurrences of *Eritrichum howardii*, located in Park, Sheridan, and Johnson counties. Three occurrences are on National Forest System lands, and two are on public lands administered by the Bureau of Land Management (BLM). One Wyoming occurrence is on lands managed by The Nature Conservancy at Heart Mountain Ranch, and two are on private land.

Eritrichum howardii is more common in Montana (USFS Region 1), where it is reported from occurrences in twelve counties. Exact locations were not reported on specimen labels, so it was difficult to determine land status of all occurrences. Two occurrences are on lands managed by the National Park Service in the Bighorn Canyon National Recreation Area and possibly from Glacier National Park, but the latter occurrence has not been seen since 1921.

Eritrichum howardii is not included on the sensitive species list for any USFS Region. It is not listed as threatened or endangered under the federal Endangered Species Act, nor is it on the sensitive species lists maintained by the BLM for Wyoming or Montana. *Eritrichum howardii* is not considered sensitive by any state agency in Montana or Wyoming.

The global Natural Heritage Program status rank for *Eritrichum howardii* is G4 (uncommon but not rare; apparently secure, but with cause for some long-term concern). In Wyoming, the species is ranked S1 (critically imperiled because of extreme rarity and especially vulnerable to extirpation from the state), and in Montana it is ranked S3 (vulnerable to extirpation in the state due to a restricted range, relatively few populations, recent and widespread declines, or other factors).

It should be noted that authorities differ as to the correct spelling of the genus. The original spelling of the genus is *Eritrichum*, and this is the name used in this assessment. However, the USDA PLANTS database, NatureServe, and WYNDD all spell the genus "*Eritrichium*."

Primary Threats

Concern for the viability of *Eritrichum howardii* on National Forest System land within Region 2 reflects its limited abundance and restricted distribution at the periphery of the species' range. Occurrences on National Forest System land in Region 2 are mostly small or the size is unknown. Current threats are difficult to identify due to the remoteness of occurrences and lack of information. Therefore, the assumption made in this assessment is that most montane, foothill, and subalpine areas are subject to a range of general potential threats that occur in these habitats, including fire, grazing, invasive species, and impacts from hikers or off-road vehicle use. Threats to *E. howardii* identified by WYNND include potential residential development of the lower foothills of Heart Mountain and an indication that road development or ORV travel could negatively affect individuals. Other potential threats to the species include air pollution (acid rain and nitrogen deposition), extreme weather events, and global warming.

The remote location of the known occurrences of *Eritrichum howardii* provides this species a degree of protection. However, land managers need to be made aware of occurrences in order to make informed management decisions. The Nature Conservancy has acquired property at Heart Mountain Ranch in 1999, protecting more than 15,000 acres of land for a suite of rare plant species, including *E. howardii*.

Primary Conservation Elements, Management Implications and Considerations

Eritrichum howardii is a mat-forming species of foothill, montane, and occasionally subalpine habitats. It tends to occur in open, sparsely vegetated sites with little shade and most often on calcareous soils. The paucity of data available concerning populations and abundance does not allow us to infer whether populations are increasing, decreasing, or remaining stable. The protection of occurrences within Region 2 is important to the conservation of the species as a whole because Wyoming occurrences represent populations at the periphery of the range. Protection of populations and their habitat is necessary for maintaining the viability of *E. howardii* on National Forest System land within Region 2. Avoiding direct impacts and disturbance to the species and its habitat will enable the species to persist. Studies to acquire basic information concerning the distribution, biology, and ecology of the species would provide land managers with the tools to manage and conserve occurrences and habitat. These studies include surveying for new occurrences, gathering current population census information on known occurrences, evaluating reproductive and ecological characteristics (e.g., pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting, dispersal vectors), gathering information on demographics (e.g., life history stages, population structure, longevity, mortality), and determining impacts to population viability from management activities and natural disturbances.

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EDITORS: Janet Coles and Kathy Roche, USDA Forest Service, Rocky Mountain Region

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Eritrichum howardii* (Howard's alpine forget-me-not) is the focus of an assessment because of its limited global distribution and abundance and a lack of knowledge concerning its distribution, habitat, population trends, or threats. This species may require special management; therefore, knowledge of its biology and ecology is critical.

This assessment addresses what is known about the biology of *Eritrichum howardii* throughout its range, including National Forest System land within Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere, and examines the success of those recommendations that have been implemented.

Scope

This assessment examines the biology, ecology, conservation, and management of *Eritrichum howardii* with specific reference to the geographic and ecological characteristics of Region 2. Although some of the literature on the species may originate from field investigations outside the region (i.e., Montana), this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *E. howardii* in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, the authors reviewed peer-reviewed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. The assessment emphasizes refereed literature because this is the accepted standard in science, but very little information concerning *Eritrichum howardii* exists in the primary literature. Refereed literature was available for the discussion of systematics and morphological descriptions, but no peer-reviewed literature exists that describes population trends, autecology, reproductive characteristics, or demography directly related to *E. howardii*. Non-refereed publications or reports were used when refereed information was unavailable, but these were regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the species' geographic distribution and abundance. These data required special attention because of the diversity of persons and methods used in collection.

Data for this species assessment were obtained from secondary sources through state natural heritage programs, including the WYNDD and the Montana Natural Resource Information System. Other information used in producing this assessment includes herbarium specimen label data, scientific literature, and knowledgeable individuals. Fifty-three herbaria within Region 2 and surrounding states were contacted. Of the institutions that responded, four herbaria contain pertinent data: the Rocky Mountain Herbarium Laramie, Wyoming (RM); the University of Colorado Museum Boulder, Colorado (COLO); Montana State University Herbarium Bozeman, Montana (MONT); and the University of Idaho Stillinger Herbarium Moscow, Idaho (ID). Literature describing closely related taxa was reviewed, and inferences were drawn where reasonable and when a basis could be established for application to *Eritrichum howardii*. The authors present no empirical data.

Treatment of Uncertainty

Science is a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with

uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hilborn and Mangel 1997) as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). As in geology, it can be difficult to conduct critical experiments in ecology, so observation, inference, good thinking, and models can be used to guide our understanding of the world (Hilborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and used in synthesis for this assessment.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication will facilitate revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project are peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The global Natural Heritage Program status rank for *Eritrichum howardii* is G4 (apparently secure, but with cause for some long-term concern; NatureServe 2006). In Wyoming, *E. howardii* is ranked S1 (critically imperiled in the state because of extreme rarity), and in Montana, it is ranked S3 (vulnerable in the state). **Figure 1** illustrates the distribution of *E. howardii* in North America and the conservation status of the species in the states where it occurs.

Eritrichum howardii is not included on the sensitive species list for Region 2 or any other region of the USFS (USDA Forest Service 2003b). *Eritrichum howardii* is not listed as threatened or endangered under the federal Endangered Species Act (U.S. Fish and Wildlife Service 2004), nor has it ever been a candidate for listing. Some *E. howardii* occurrences are on public lands managed by the BLM, but it is not listed as a BLM sensitive species in Wyoming or Montana (Bureau of Land Management 2002, 2003). The Montana Natural Resource Information System does not track abundance of the species, and no abundance estimates were available (Mincemoyer personal communication 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Within Region 2, eight occurrences of *Eritrichum howardii* have been reported in Wyoming, with documented locations in Sheridan, Park, and Johnson counties (**Figure 2**). Five of these occurrences are on public land: two on the Shoshone National Forest, one on the Bighorn National Forest, one on BLM lands managed by the Cody Field Office, and one on BLM lands managed by the Buffalo Field Office. Because the species lacks sensitive status, it is not specifically protected on USFS or BLM land. Two occurrences are located on private land, and one occurrence is on lands managed by The Nature Conservancy at Heart Mountain Ranch. Management objectives at Heart Mountain Ranch include protection of *E. howardii* (Bell personal communication 2006). No location information is available concerning the historical occurrence located in the foothills between Sheridan and Buffalo, Wyoming.

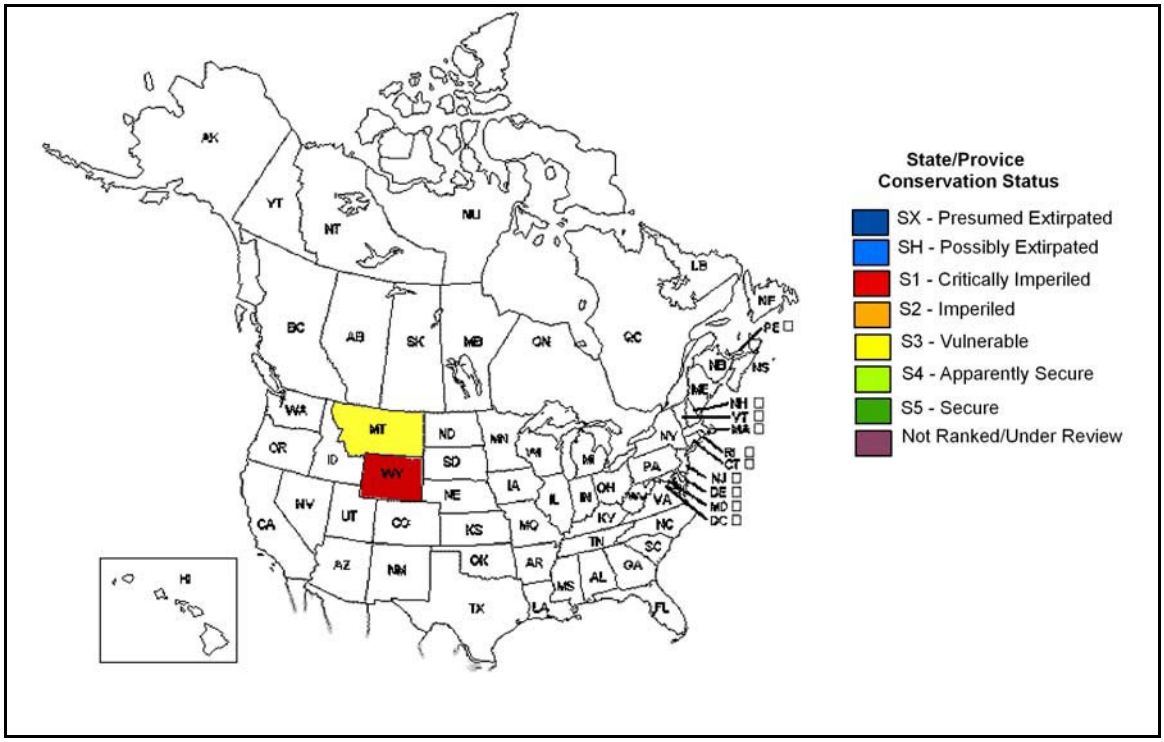

Figure 1. Distribution of *Eritrichum howardii* in North America and conservation status of the species in the states where it occurs (NatureServe Explorer 2006).

Outside of Region 2, eleven herbarium specimens from the Rocky Mountain Herbarium indicated that the species was present at least historically in Fergus, Meahger, Sweet Grass, Carbon, Jefferson, and Lewis and Clark counties in Montana (**Figure 3**). The Montana State University Herbarium reported additional occurrences in Chouteau, Cascade, Judith Basin, Wheatland, Park, and Gallatin counties (Hjalmarsson personal communication 2004). Precise locations were not reported on specimen labels, so it is difficult to determine the land status of most of the Montana occurrences. However, one occurrence was reported on the Custer National Forest, two on the Helena National Forest, and one on the Lewis and Clark National Forest. One occurrence is reported from the Bighorn Canyon National Recreation Area managed by the National Park Service (Rapp personal communication 2006). An historical location is within Glacier National Park (Standley 1921), but *E. howardii* is not included in the *Flora of Glacier National Park* (Lesica and McNeil 2002).

National Forest System lands in Region 2 supporting *Eritrichum howardii* are managed according to the standards and guidelines of the Shoshone National Forest Land and Resource Management Plan (USDA Forest Service 1986) and the Bighorn National Forest Revised Land and Resource Management Plan (USDA Forest Service 2005). Although *E. howardii* is not considered a sensitive species on either national forest, the National Forest Management Act and its rules require the USFS to sustain habitats that support healthy populations of existing plant and animal species on the national forests and grasslands. Project-specific National Environmental Policy Act compliance does not require evaluation of project alternatives with respect to *E. howardii* occurrences. No specific management or conservation plan is in place for protection of this species on National Forest System lands. The Shoshone National Forest has proposed the creation of the Bald Ridge Research Natural Area (RNA), in part to protect occurrences of *E. howardii* (Fertig and Bynum 2004). The Bighorn National Forest established the Mann Creek RNA (USDA Forest Service 2005); this RNA will protect one occurrence on the Bighorn National Forest. RNAs form a long-term network of ecological reserves designated for non-manipulative research and education and the maintenance of biological diversity. No other specific management or conservation plan is in place for protection of this species on National Forest System land.

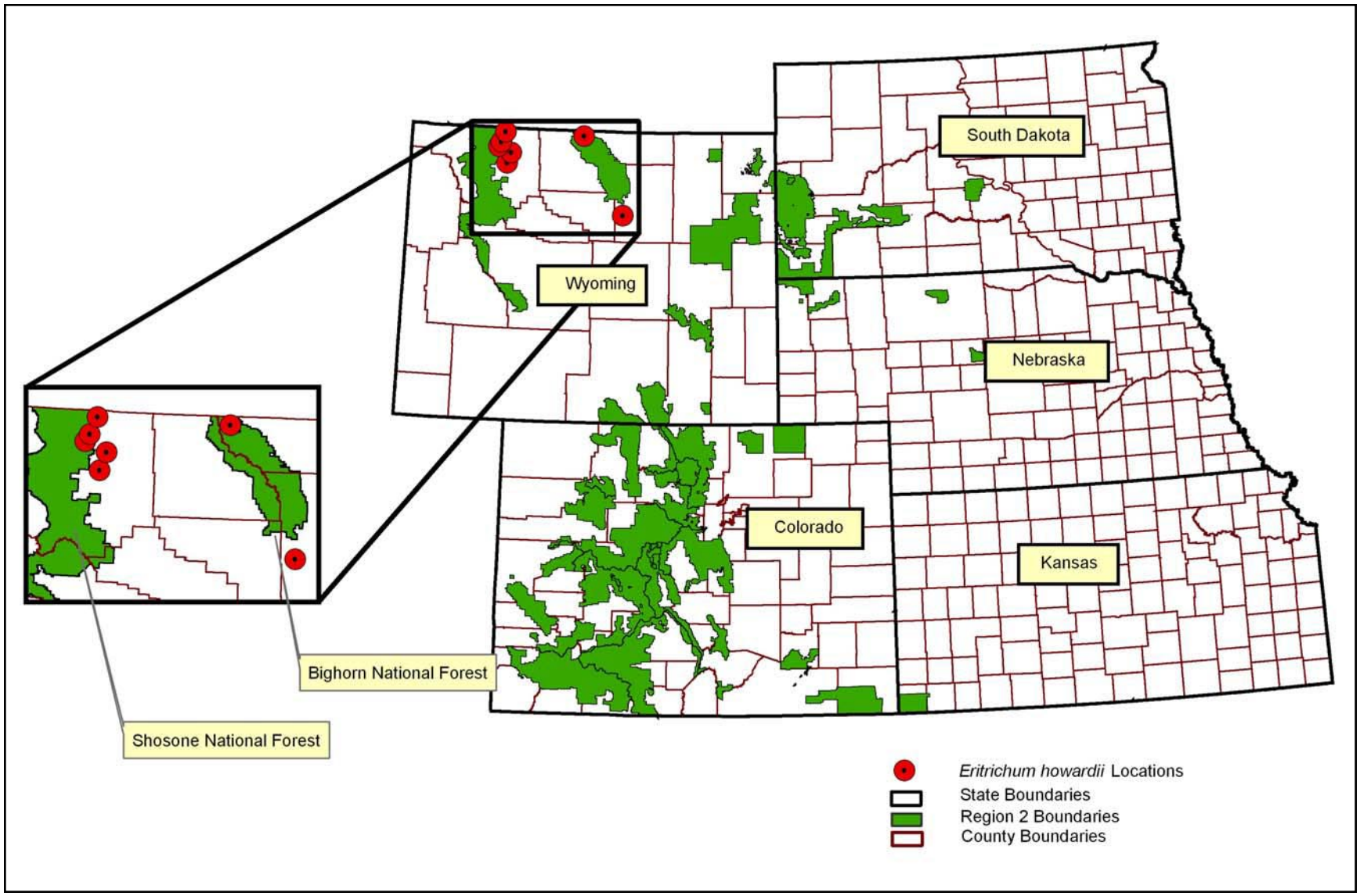

Figure 2. General location of *Eritrichum howardii* occurrences in USDA Forest Service Region 2.

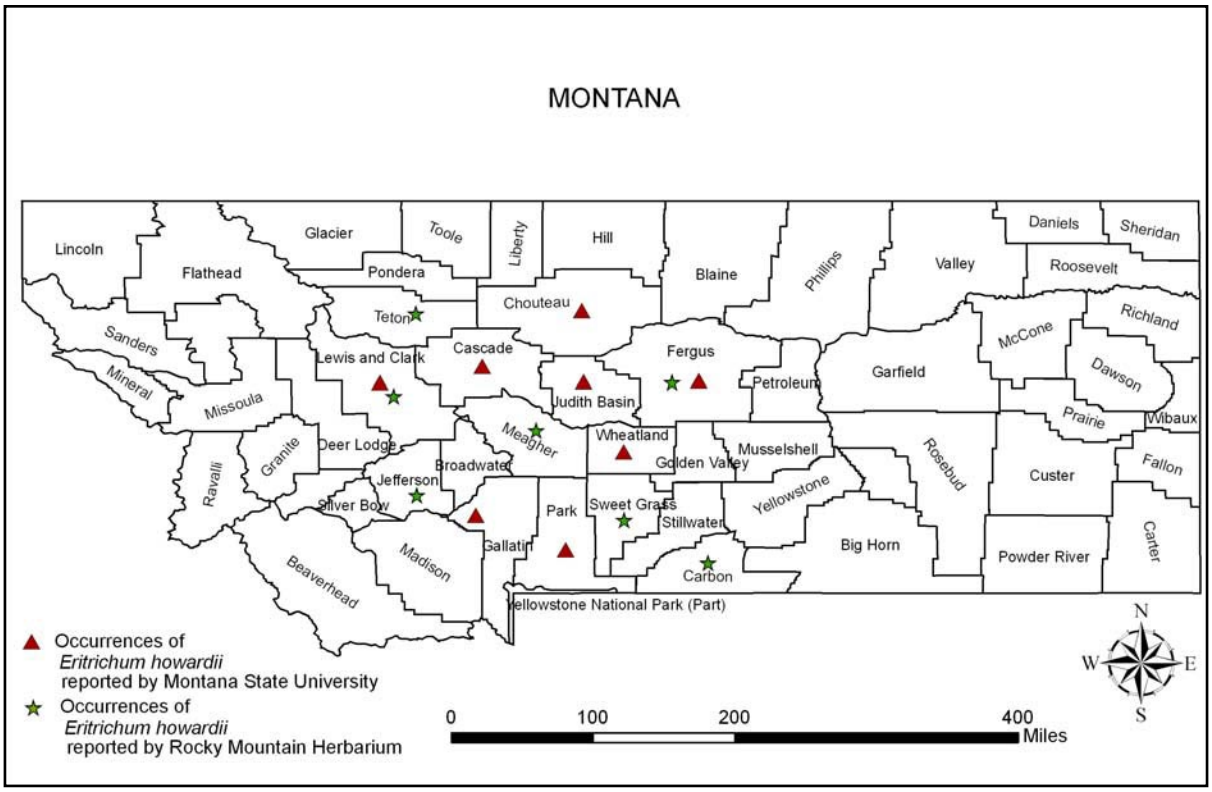

Figure 3. General location of *Eritrichum howardii* occurrences in Montana as reported by Rocky Mountain Herbarium and Montana State University Herbarium.

Management of BLM public lands is currently conducted according to the Resource Management Plan for the Cody Resource Area (Bureau of Land Management 1990) and the Buffalo Resource Area (Bureau of Land Management 2001). BLM Manual 6840 establishes Special Status Species policy for plant species and the habitats on which they depend. *Eritrichum howardii* is not listed as a Special Status Species by BLM in Wyoming or Montana. No conservation strategies or management plans are in place for protection of this species on BLM land.

Occurrences of *Eritrichum howardii* on National Park Service land, private land managed by the Nature Conservancy at Heart Mountain, and in the Mann Creek RNA on the Bighorn National Forest are afforded protection based on management prescriptions for those areas. However, existing laws and regulations do not adequately protect populations of this species on National Forest System land because no species-specific protective mechanisms are in place. The remote location of occurrences may provide some protection. However, there is a lack of knowledge concerning the reproductive and ecological characteristics, demographics, and impacts to population viability from management activities and natural disturbances.

Biology and Ecology

Classification and description

Systematics and synonymy

Eritrichum howardii is a member of the Boraginaceae (Borage family), which includes 117 genera and approximately 2400 species (Zomlefer 1994). The Boraginaceae is cosmopolitan in distribution, with centers of diversity in the Mediterranean and western North America. North American representatives include approximately 34 genera and 384 species (Zomlefer 1994). The largest genera include *Cryptantha*, *Plagiobothrys*, and *Hackelia*.

The taxonomy of the Boraginaceae appears to be relatively stable. An extensive literature search found no recent phylogenetic studies for this group. The genus *Eritrichum* is centered in Eurasia (Weber 2003). There are currently three species of *Eritrichum* recognized in North America: *E. howardii*, *E. splendens* Kearney, and *E. nanum* (Vill.) Schrad. ex Gaudin. *Eritrichum splendens* occurs in Alaska. There are four recognized varieties of *E. nanum* that are distributed across the Rocky Mountains north to Canada and Alaska. Of the

four varieties, *E. nanum* var. *elongatum* is known to co-occur with *E. howardii*.

There are two synonyms associated with *Eritrichum howardii*; the species was first described in 1878 as *Cynoglossum howardii* A. Gray, and it was later assigned to *Omphalodes howardii* (A. Gray) A. Gray in 1885 (Hitchcock et al. 1959). In 1900, Rydberg placed this taxon in *Eritrichum*, under the specific epithet *E. howardii*. **Table 1** summarizes the nomenclatural history of *E. howardii*.

The original spelling of the genus is *Eritrichum* rather than *Eritrichium*. The genus was first described by Schrader (1820), but when it was revised by Gaudin (1828) it was misspelled as *Eritrichium*. The rules of botanical nomenclature require that the original spelling has priority; therefore "*Eritrichum*" is used in this assessment. It should be noted that the USDA PLANTS database, NatureServe, and WYNDD all use the *Eritrichium* spelling of the genus.

History of species

Eritrichum howardii has only been collected in two states in the United States. Winslow J. Howard apparently made the earliest collection of *E. howardii* in North America around 1866 in the Rocky Mountains of the Montana territory (Wight 1902). The Howard collection was originally misidentified as *Eritrichum aretioides*. Howard's collection is the type specimen, and Gray named the species after him. There is no date on the type specimen, but Gray described it in 1878, placing the discovery in the mid to late 1870s. *Eritrichum howardii* was collected for the first time in Wyoming in approximately 1900 by Frank Tweedy. The history of the Wyoming collections continues in 1950 when Porter discovered it in Park County. *Eritrichum howardii* was periodically documented in the late 1970s and early 1980s. The majority of collections were made in 1989 and 1996. The most recent Wyoming collection was made by Dave Rosenthal in 1997 as part of his floristic study of the Northern Absaroka Mountains (Rosenthal 1999). It was documented in Montana periodically through the early 1900s to the present.

Non-technical description

The Boraginaceae are typically pubescent, sometimes scabrous or hispid. The corollas are united, and the inflorescence is typically cymose, often helicoid or scorpioid (Zomlefer 1994). Fruits generally consist of four nutlets, derived from a two-carpellate schizocarp, as seen in *Eritrichum*.

Eritrichum howardii is a densely matted, long-lived perennial herb under 10 cm tall. The plant often appears stemless. The leaves are densely silvery-hairy and narrowly oblanceolate with acute tips. The flowers are bright blue and showy (5 to 9 mm wide), with a yellow center or eye. The flowers are borne in dense clusters at the tip of the stems. The fruit consists of one to four hairy nutlets (Hitchcock et al. 1959, Dorn 1992, Fertig 2000). **Figure 4** is a line drawing of *E. howardii* illustrating flowers and fruit. **Figure 5** is a photograph of *E. howardii* showing the blue color of the flowers and the cushion habit.

Eritrichum howardii can be confused with *E. nanum* or members of the genus *Myosotis*. *Eritrichum howardii* can be distinguished from *E. nanum* by differences in leaf vestiture (hairs); *E. nanum* has loosely hairy, green leaves with an obvious tuft of long hairs at the tips, whereas *E. howardii* leaves are densely-silvery with no apparent tuft of hairs at the tips. *Eritrichum nanum* usually occurs at higher elevations than *E. howardii*. Six taxa of *Myosotis* occur in Wyoming; four are introduced, and two are native. Only one species of *Myosotis*, *M. asiatica* (Vesterg.) Schischkin & Sergievskaja, may co-

Table 1. Classification of *Eritrichum howardii* (Hitchcock et al. 1959)

***Eritrichum howardii* (Gray) Rydberg**
Family: Boraginaceae
Genus: *Eritrichum*
Species: *Eritrichum howardii*
Citation: *Eritrichum howardii* (Gray) Rydberg, Mem. N.Y. Bot. Gard. 1:327. 1900. *Omphalodes howardii* (A. Gray) A. Gray, Proc. Am. Acad. 20:263. 1885. *Cynoglossum howardii* A. Gray, Synoptical Flora of North America 2(1):1878.
Synonyms: *Cynoglossum howardii* A. Gray, *Omphalodes howardii* (A. Gray) A. Gray.
Vernacular Name: Howard's forget-me-not
Type: *Cynoglossum howardii* A. Gray. TYPE: U.S.A. Montana Territory. *Winslow J. Howard*. 1866 (NY!)

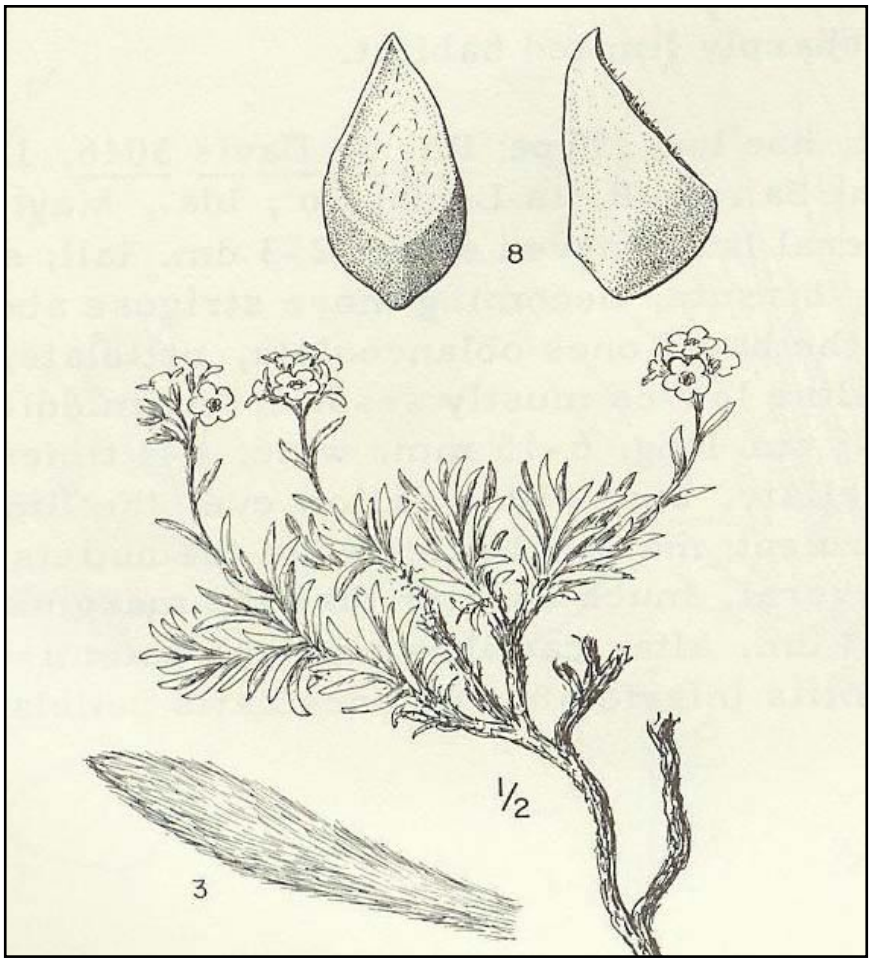

Figure 4. Line drawing of *Eritrichum howardii* showing life form, leaf pubescence, flowers, and fruit. Drawing by J. Janish from the Vascular Plants of the Pacific Northwest, Part 4 (Hitchcock et al. 1959).

Figure 5. Photograph of *Eritrichum howardii* in flower, illustrating blue color of the flowers and cushion habit. Used by permission of the photographer, Jan Hjalmarsson of Montana Plant Life, http://montana.plant-life.org.

occur with *E. howardii* in Wyoming and Montana. Members of *Myosotis* typically have elongate stems and inflorescences whereas *E. howardii* has a compact inflorescence and stems (Fertig 2000).

A technical description and an illustration of this species appear in Hitchcock et al. (1959). Dorn (1992) includes a key to *Eritrichum* in Wyoming. Additional photos and illustrations are available on the WYNDD online state species abstract (Wyoming Natural Diversity Database 2004).

Distribution and abundance

The historic and current global distribution of *Eritrichum howardii* is the Rocky Mountain Province as defined by Takhtajan (1986). *Eritrichum howardii* occurs across Montana and Wyoming. (Hitchcock et al. 1959, Fertig 2000). This species is documented in twelve Montana counties.

No rigorous abundance estimates are available for Montana occurrences of *Eritrichum howardii* (Mincemoyer personal communication 2004). Montana botanists have reported the species as frequently encountered on rocky slopes and ridges in alpine and subalpine habitats; however, it is never locally abundant (Hjalmarsson personal communication 2004, Shelly personal communication 2006).

Eritrichum howardii has been reported from the Cascade Mountains of Washington; however, this occurrence has never been verified and is based upon a single collection made by Tweedy in 1882. Its presence in western Washington is doubtful and has been attributed to mislabeling (Johnston 1924, Hitchcock et al. 1959). It has also been reported from Idaho, but no voucher specimens or checklists could be discovered to verify any locations in that state. Curators from all herbaria in Idaho were contacted, and no record of this species in Idaho was discovered. Earlier reports of its distribution in Idaho are attributed to error.

Within Region 2, *Eritrichum howardii* exhibits a discontinuous distribution across Wyoming, occupying suitable habitat in the mountains and foothills. WYNDD reports eight occurrences of *E. howardii* in Park, Sheridan, and Johnson counties (**Table 2**). All of the occurrences in the WYNDD databases are documented by voucher specimens deposited in herbaria, including the Rocky Mountain Herbarium (RM) and the University of Colorado Museum (COLO).

Abundance information for *Eritrichum howardii* within Region 2 is scarce to nonexistent. An accurate estimation of ecological density in the statistical sense is not possible given the available data. Abundance data exist only as a single casual field estimate ("30 to 50 plants in 0.2 hectare") observed in 1979 (WY #003 in **Table 2**). In 1996, the collector of WY #005 (**Table 2**) noted that the species was "locally common but restricted to a limited area." Several occurrences consist of multiple sub-occurrences. **Table 2** reports the number of sub-occurrences comprising each occurrence. The extent of known occurrences is likewise poorly documented. Ron Hartman, curator of the Rocky Mountain Herbarium, noted that the largest population he observed was a few acres in size in the early 1980s (Hartman personal communication 2004).

A very rough estimate of the total population in Region 2, based on the available data and communication with knowledgeable botanist, is at least several hundred individuals. Abundance data are summarized in **Table 2**.

Population trend

No inferences can be made concerning population trends of *Eritrichum howardii*. There have been no population trend studies for this species within Region 2 or elsewhere. Only four of the eight known locations have been revisited. Abundance data were seldom recorded and were never rigorously quantified. Therefore, it is impossible to make even a rudimentary inference of population trends. All that is known is that *E. howardii* occurs in a clumped pattern, sometimes forming extensive mats on open, often rocky slopes in the foothills, montane, and occasionally extending into the subalpine.

Habitat

Eritrichum howardii is a cushion-like, mat-forming species that tends to occur in more or less open, sparsely vegetated sites with little shade, most often on calcareous soils. **Table 2** summarizes habitat data taken from herbarium label data and occurrence records, including associated vegetation, elevation, substrate, slope, and aspect.

In Region 2, *Eritrichum howardii*'s range is included within the Yellowstone Highlands and Bighorn Mountains sections of the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-

Table 2. Summary of abundance and habitat data for known occurrences of *Eritrichum howardii* in Wyoming and Montana, taken from Wyoming Natural Diversity Database records and herbarium label data.

Element Occurrence Record and Collection #	Collection Date	County	Area (ha)	Number of Populations	Total Number of Plants	Land Ownership/ Management (Herbarium)[1]	Elevation (m)	Aspect	Substrate	Slope (%)	Habitat Characteristics and Association
WYOMING LOCATIONS											
WY EO #001 *Tweedy #3572*	15 July 1900	Sheridan	Not reported	1	Not reported	Not reported (RM)	1,524	Not reported	Not reported	Not reported	Rolling plains and foothills
WY EO #003 Porter #5422, *Rosenthal #1201*, and *Dorn #3156*	11 July 1950 22 June 1997 26 July 1978	Park	0.2	2	30 to 50	Clarks Fork Ranger District Shoshone National Forest (RM)	1,524 to 2,438	W, NW, E-facing	Limestone, dolomite, Mesozoic and Paleozoic rocks	Not reported	Spruce-fir forest and meadows to ridge; rocky slopes
WY EO #004 *Evert #17136* and *#3197*	25 June 1989 17 July 1981	Park	Not reported	2	Not reported	BLM Cody Field Office (RM)	2,560 to 2,743	S, E, W-facing	Limestone	Not reported	Open Douglas-fir/ limber pine forest/ meadow parkland
WY EO #005 *Fertig #17044*	8 August 1996	Sheridan	Not reported	1	Not reported	Medicine Wheel Ranger District Bighorn National Forest (RM)	2,255 to 2,438	W-facing	Redbed clays at top of dolomite cliffs	Not reported	Cushion plant community on rim of canyon
WY EO #006 *Hartman #54701*, *Nelson #12481*, *#16665*, *#16689*, *#16657*, and *Fertig #16852*	13 June 1996 25 June 1989 19 June 1989 15 July 1996	Park	Not reported	5	Not reported	Clarks Fork Ranger District Shoshone National Forest (RM)	1,524 to 2,438	W, E, SE-facing	Redbeds, sandstone and shale, limestone, gravelly	Not reported	Rocky grassland, scattered patches of gravel beds with cushion plants and occasional limber pine; also on knoll
WY EO #007 *Hartman #9775*	28 Jun 1979	Johnson	Not reported	1	Not reported	BLM Buffalo Field Office (RM)	2,438	W-facing	Limestone outcrops	Not reported	Grassy slopes
WY EO #008 *Hartman #13467*, *Fertig #17635*, and *Evert #5416*	1 July 1981 30 June 1997 13 July 1983	Park	"several acres"	3	Population covering several acres, potentially several hundred.	Big Horn Basin Private (RM)	2,133 to 2,377	W, NW-facing	Limestone cap rock and talus, broken dolomite boulders	Not reported	Cliffs and upper slopes with *Pinus flexilis*, *Picea glauca*, and *Pseudotsuga menziesii*; cushion plant community in boulder rock fields

Table 2 (cont.).

Element Occurrence Record and Collection #	Collection Date	County	Area (ha)	Number of Populations	Total Number of Plants	Land Ownership/ Management (Herbarium)[1]	Elevation (m)	Aspect	Substrate	Slope (%)	Habitat Characteristics and Association
WY EO #009 *Hartman #54638*	12 June 1996	Park	Not reported	1	Not reported	Private (RM)	1,798 to 1,859	W, SW-facing	Intrusive igneous rocks	Not reported	Grassy slopes
MONTANA LOCATIONS											
Major and *Bamberg #1046* *Bamberg #764*	26 July 1962 31 July 1963	Fergus	Not reported	2	Not reported	? Big Snowy Peak (COLO)	2,500 to 2,651	Not reported	Rock and gravel	Not reported	Open gravelly stand
Kelsey (June 1888)	June 1888	Meahger	Not reported	1	Not reported	? Helena Montana (COLO)	Not reported	Not reported	Not reported	Not reported	Not reported
Lackschewitz #4403	6 July 1973	Teton	Not reported	1	Not reported	? South Fork of the Teton River (RM)	1,524	N-facing	Limestone	Not reported	Steep north facing limestone cliffs
Evert #25807	9 July 1993	Sweet Grass	Not reported	1	Not reported	Custer National Forest, Beartooth Mountains (RM)	1,980 to 2,040	Not reported	Limestone outcroppings	Not reported	Limestone outcroppings with *Rhus trilobata*, *Sedum lanceolatum*, and *Penstemon attenuatus*
Evert #19054	18 June 1990	Carbon	Not reported	1	Not reported	? East flank of the Beartooth Range (RM)	1,790	Not reported	Limestone derived substrates	Not reported	*Pinus flexilis* woodland with some Douglas fir with *Poa cusickii* and *Hymenoxys acaulis*
Hitchcock and *Muhlick #12036* and *#11921*	6 July 1945 3 July 1945	Fergus	Not reported	1	Not reported	? Big Snowy Mountains above Half Moon Canyon (RM)	Not reported	Not reported	Limestone cliffs and outcrop	Not reported	High Plateau
Vanderhorst #4922	4 June 1993	Jefferson	Not reported	1	Not reported	? Doherty Mountain (RM)	1,880	Not reported	Limestone pavement and gravel	Not reported	Not reported
White #346	21 May 1939	Lewis and Clark	Not reported	1	Not reported	Helena National Forest (in 1939) (RM)	1,210	Not reported	Deep rocky clay	30	Open timber-yellow pine

Table 2 (concluded).

Element Occurrence Record and Collection #	Collection Date	County	Area (ha)	Number of Populations	Total Number of Plants	Land Ownership/ Management (Herbarium)[1]	Elevation (m)	Aspect	Substrate	Slope (%)	Habitat Characteristics and Association
White #347	28 May 1939	Meagher	Not reported	1	Not reported	Helena National Forest (in 1939) (RM)	2,130	SW-facing	Shallow rocky loam	30	Open exposed grass land
White #345	25 June 1939	Meagher	Not reported	1	Not reported	Lewis and Clark National Forest (in 1939) (RM)	2,130	E-facing	Shallow rocky loam	15	High exposed open grassy ridge top
Paxton #18	June 1909	Meagher	Not reported	1	Not reported	Helena, Montana (RM)	Not reported	Not reported	Not reported	Not reported	Not reported

[1]Herbarium indicates where specimen is deposited: RM = Rocky Mountain Herbarium, COLO = University of Colorado Museum.

Alpine Meadow Province (McNab and Avers 1994). This species also has documented occurrences in several sections of the Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow Province (primarily within USFS Regions 1 and 4).

Habitat information from Montana herbarium specimens of *Eritrichum howardii* consistently note occurrences on open, exposed ridges or grassy slopes, sometimes associated with *Pinus flexilis* (limber pine). Substrates include deep red clay, dolomite, and limestone. Slope was noted to be 10 to 30 percent on west, north, and east exposures. Elevations range from 1,219 to 2,651 m. The Wyoming habitat descriptions are similar to the Montana observations, except they lack information on percent slope.

On National Forest System land within Region 2, *Eritrichum howardii* is restricted to sparsely vegetated areas. This species is most often found on ridge tops and slopes where wind exposure is high and vegetation sparse. These habitats may superficially resemble alpine tundra in the lack of shrubs and tall trees (probably due to the high winds), but they typically occur at much lower elevations (Fertig personal communication 2004). *Eritrichum howardii* is commonly found in two types of vegetation communities, *Pseudotsuga menziesii* (Douglas-fir) and *Pinus flexilis* forests, and in grasslands dominated by *Koeleria macrantha* (prairie junegrass) and *Festuca idahoensis* (Idaho fescue). Within both of these communities, *E. howardii* is located in sparsely vegetated openings. Other associated trees and shrubs noted on herbarium label data include *Rhus trilobata* (skunkbush sumac) and *Picea glauca* (white spruce). One occurrence (WY #003 in **Table 2**) was collected from a spruce-fir association along a ridge. No estimate of vegetation cover was reported for any site. **Table 3** lists herbaceous species occurring with *E. howardii* in Wyoming.

According to available data for *Eritrichum howardii*, Wyoming occurrences range from 1,524 to 2,743 m elevation (**Table 2**). **Figure 6** shows that the majority of occurrences are located between 2,000 and 2,500 m. Upper tree line in Wyoming ranges from 3,500 m in southern Wyoming to 3,000 m in the north (Knight 1994). *Eritrichum howardii* can occur as high as 2,743 m, but it has not been documented in the Wyoming alpine where its relative *E. nanum* is common. Typical aspects recorded for this species include south, southeast, west, northwest, southwest, and east. No northern exposures were noted for the eight Wyoming occurrences. It has been documented on north-facing slopes in Montana. Occurrences above 2,500 m (WY #003 and #004 in **Table 2**) tend to be oriented to warmer south, west, and southwest aspects.

The primary substrate for *Eritrichum howardii* in Wyoming consists of dry, gravelly calcareous substrates. Habitat descriptions of Wyoming occurrences consistently note that this species occurs on coarse soils containing cobbles and/or gravels derived from local limestones or dolomites, including Madison limestone, Bighorn dolomite, and Gallatin limestone. Herbarium label data and the digital geologic map of Wyoming (U.S. Geological Survey 1994) indicate that WY #009 (**Table 2**) occurs on a complex of intrusive and igneous rocks, the Thorofare Creek group and the Wiggins Formation. It is possible that calcareous conditions may exist at this site, but are undetectable in the field. Plants that are characteristic of limestone and other base-rich, neutral to alkaline soils are loosely termed calcicoles (Lincoln et al. 1982). *Eritrichum howardii* is associated with a suite of calcicoles growing on dry, gravelly, calcareous substrates (Fertig personal communication 2004). Examples of other calcicoles occasionally sharing habitat with *E. howardii* include *Shoshonea pulvinata* (Shoshone carrot), *Pyrrocoma carthamoides* var. *subsquarrosa* (largeflower goldenweed) and *Kelseya uniflora* (oneflower kelseya). Both *S. pulvinata* and *P. carthamoides* var. *subsquarrosa* are designated sensitive species in Region 2.

Pinus flexilis is considered a climax tree on extremely harsh sites such as windswept ridges and steep slopes, the same conditions where *Eritrichum howardii* may occur. At higher elevations (above 2,500 m), this species occupies open ridges and slopes in *Picea engelmannii* forests, also considered a climax species (Knight 1994, Jones and Ogle 2000, Welp et al. 2000) under more moderate conditions.

Reproductive biology and autecology

An extensive literature search found no empirical data describing the ecological strategies of *Eritrichum howardii*. Grime (1979) developed a system of classifying plant strategies based on a species' response to stress. He termed these responses competitor, stress tolerant, and ruderal. Life history patterns have also been described as *r*- and *K*-selected, where *r*-selected species typically allocate more resources to reproduction and *K*-selected species allocate more resources to survival. This system should be viewed as a continuum between the two resource allocation strategies (MacArthur and Wilson 1967).

Table 3. Vascular plant species associated with *Eritrichum howardii*. List generated from herbarium label and Wyoming Natural Diversity Database data.

Scientific Name	Common Name
Androsace chamaejasme Wulfen	sweetflower rockjasmine
Antennaria aromatica Evert	scented pussytoes
Arenaria congesta Nutt.	ballhead sandwort
Arenaria hookeri Nutt.	Hooker's sandwort
Artemisia campestris L. ssp. *borealis* (Pallas) Hall & Clements	field sagewort
Besseya wyomingensis (A. Nels.) Rydb.	Wyoming besseya
Castilleja nivea Pennell & Ownbey	snow Indian paintbrush
Ericameria nauseosa (Pallas ex Pursh) Nesom & Baird	rubber rabbitbrush
Comandra umbellata (L.) Nutt.	bastard toadflax
Cryptantha spiculifera (Piper) Payson	Snake River cryptantha
Cymopterus terebinthinus (Hook.) Torr. & Gray	turpentine wavewing
Elymus spicatus (Pursh) Gould	bluebunch wheatgrass
Erigeron spp.	fleabane
Erigeron caespitosus Nutt.	tufted fleabane
Eritrichum nanum (Vill.) Schrad. ex Gaudin	Arctic alpine forget-me-not
Festuca hallii (Vasey) Piper	plains rough fescue
Festuca idahoensis Elmer	Idaho Fescue
Haplopappus armerioides (Nutt.) Gray	thrift mock goldenweed
Hymenoxys acaulis (Pursh) Parker var. *caespitosa* (A. Nels.) Parker	caespitose four-nerve daisy
Kelseya uniflora (S. Wats.) Rydb	oneflower kelseya
Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass
Lesquerella S. Wats.	bladderpod
Leucopoa kingii (S. Wats.) W.A. Weber	spike fescue
Minuartia obtusiloba (Rydb.) House	twinflower sandwort
Oxytropis besseyi (Rydb.) Blank	Bessey's locoweed
Oxytropis sericea Nutt.	white locoweed
Penstemon attenuatus Dougl. ex Lindl. var. *pseudoprocerus* (Rydb.) Cronq.	small penstemon
Petrophyton caespitosum (Nutt.) Rydb.	mat rockspirea
Poa cusickii Vasey	Cusick's bluegrass
Pentaphylloides floribunda (Pursh) A. Löve nom. super.	shrubby cinquefoil
Sedum lanceolatum Torr.	spearleaf stonecrop
Selaginella densa Rydb.	Lesser spikemoss
Shoshonea pulvinata Evert & Constance	Shoshone carrot
Trisetum spicatum (L.) Richter	spike trisetum

In reality, species can exhibit any combination of ruderal, competitor, and stress tolerant responses. There are not enough data to classify *Eritrichum howardii* definitively. Given the harsh windswept environment in which it occurs, this taxon is more likely to be stress tolerant than either competitive or ruderal, allocating its resources to survival rather than reproduction (K-selected) (MacArthur and Wilson 1967, Grime 1979). It may be that *E. howardii* could survive in less severe habitats, but it is probably not a good competitor in mesic or resource rich sites (Fertig personal communication 2004).

These life history systems are not a definitive classification of ecological strategy; natural variability reminds us that many combinations can occur. Grime (1979) and MacArthur and Wilson's (1967) systems are useful conceptual models for classifying autecological

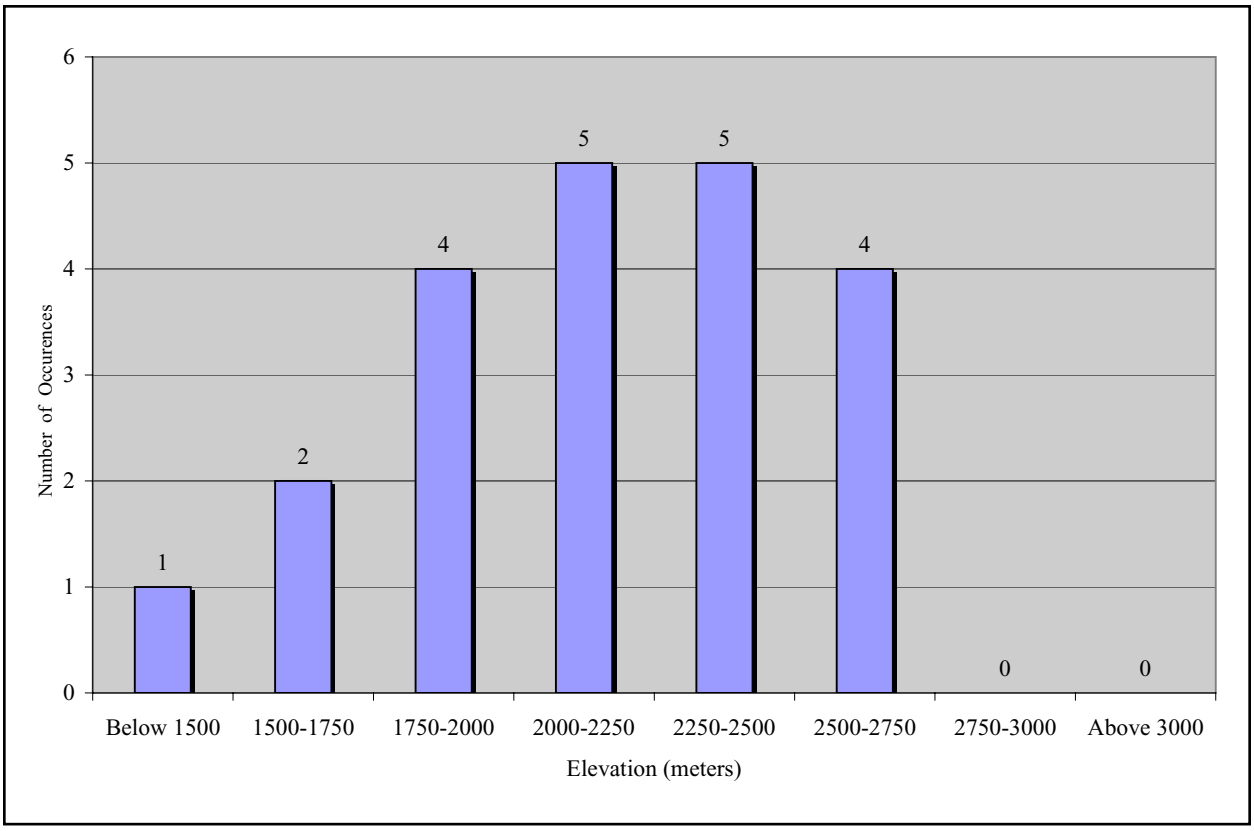

Figure 6. Elevation profile of *Eritrichum howardii* occurrences in Wyoming and Montana.

strategies of individual species, and they are functional for determining where in the broader picture an individual species can be placed.

Eritrichum howardii is monecious, reproducing sexually by seed. The inflorescence is typically a condensed cymose cluster of bright blue salverform corollas 7 to 9 mm in diameter (Wight 1902). *Eritrichum howardii* flowers from June through July, with undispersed fruits present through August (Fertig 2000). It is not known whether this species flowers consistently upon reaching reproductive maturity, how long fruits remain on the plant, or how many flowers produce seed in a given year. *Eritrichum howardii* can spread vegetatively by growth and development of the perennating bud, forming extensive mats. There are no other known cryptic phases in *E. howardii*'s life history.

No formal studies have investigated the pollination mechanisms for this species. In the Boraginaceae, entomophily is common. *Eritrichum howardii* is characterized by relatively large, showy flowers, indicating that this species is most likely insect pollinated. The individual flowers possess a yellow corona, present at the base of the corolla limbs that probably attracts pollinators (see cover photo). While specific pollinators are not known, the Boraginaceae are often pollinated by bees, butterflies, and flies (Heywood 1993, Zomlefer 1994). Some members of the family can change the color of the corolla to signal pollen availability (Zomlefer 1994), but it is not known whether *E. howardii* undergoes this color change.

No investigations into seed dispersal have been conducted for this species. Seed dispersal may occur through wind or water runoff after heavy rains or snowmelt. It is unlikely that animal interactions affect dispersal because the nutlets are devoid of any mechanism for grasping onto hairs, unlike other members of the genus (**Figure 4**). There are no reports concerning seed predation of *Eritrichum howardii* fruits.

No information is available describing the process of germination and seedling establishment for *Eritrichum howardii*. No experimental data exist concerning the fertility or viability of the seeds. According to Grime (1979), a persistent seed bank is one in which at least some of the seeds are at least one year old. We can only guess that *E. howardii* produces at least some viable seed and we assume that *E. howardii*

maintains a persistent seed bank. How long the seeds are viable is not known. No seedlings have been reported, and none of the known occurrences has been monitored to determine whether recruitment is occurring.

Members of the Boraginaceae are normally obligate outcrossers, setting little or no seed if not cross-pollinated; some members are fully self-incompatible (Heywood 1993). It is not possible to characterize definitively the breeding system of *Eritrichum howardii*. If *E. howardii* were self-fertilizing, then it would have a short-term reproductive advantage in the event that pollination agents were absent. Over the long term, however, selfing may promote homozygosity and possibly reduce fitness and the species' ability to adapt to changing environmental conditions (inbreeding depression) (Menges 1991, Weller 1994). In all probability, *E. howardii* is an outcrosser, and pollinators are probably not limiting. In this case, the species would have a long-term reproductive advantage by maintaining higher heterozygosity, but any loss of pollinators could theoretically reduce seed set (Weller 1994).

The phenomenon of gynodioecy has been observed in *Eritrichum nanum* var. *aretioides* (Puterbaugh et al. 1997). Some populations of *E. nanum* will produce both hermaphrodite and pistillate (female) flowers. This is thought to increase fecundity through increased fitness of the female flowers. In this instance, there is also an associated change in flower and seed morphology; the hermaphroditic flowers possess larger corollas than the pistillate flowers, and the pistillate flowers produce larger seeds. The larger seeds also show an increase in germination under natural conditions (Puterbaugh et al. 1997). There have been no reports of this phenomenon in *E. howardii*. However, because *E. nanum* var. *aretioides* is a congener of *E. howardii* and because both species occur in harsh environments, it is possible that this situation may occur in *E. howardii*. Careful observations of *E. howardii* populations in bloom may confirm or rule out gynodioecy in this species.

The relationship between rarity and genetic variation is a subject of increasing interest, and the notion that *all* rare species have a low level of genetic variation has been questioned (Linhart and Premoli 1993, Gitzendanner and Soltis 2000). There is no doubt that low genetic diversity does affect some rare plants' ability to reproduce and survive (Fenster and Dudash 1994, Weller 1994). Genetic factors such as inbreeding depression and outbreeding depression should be considered in analyzing the genetic fitness of a species.

Eritrichum howardii may be subject to genetic risk due to the small size and isolated nature of occurrences. Small populations of rare plants may be subject to the deleterious affects of inbreeding or the founder effect. Some small populations may actually have alleles missing from larger populations (Karron et al. 1988). It is therefore important to consider the conservation of small populations as well as larger ones. There are no data to show the extent of gene exchange among populations of *E. howardii*, but because of the distances separating most occurrences, frequent gene exchange is unlikely.

Eritrichum howardii is probably an outcrossing species, which may facilitate the risk of outbreeding depression. However, if the known occurrences of *E. howardii* were genetically and physically isolated, then the risk of outbreeding depression would be low. There is no evidence that *E. howardii* readily undergoes natural hybridization. No observations have been made concerning possible hybridization events between *E. howardii* and *E. nanum* var. *elongatum*. Given the lack of evidence and understanding, no inferences can be made by the authors concerning genetic issues possibly associated with *E. howardii*. The diploid chromosome number of *Eritrichum howardii* is unknown.

Phenotypic plasticity is defined as marked variation in the phenotype as a result of environmental influences on the genotype during development (Lincoln et al. 1982). There is no empirical evidence to suggest the presence of ecotypes in *Eritrichum howardii*. An investigation using transplant experiments would address the question of phenotypic plasticity in *E. howardii*.

Current literature indicates that relationships between most higher plants and mycorrhizal fungi are common (Barbour et al. 1987). These relationships are poorly known, and this is a growing area of scientific study. There are no documented or observed mycorrhizal associations for *Eritrichum howardii*. Mycorrhizal relationships documented in dry alpine meadow communities are important for fixing both nitrogen and phosphorus (Theodose and Bowman 1997). Mycorrhizae have been documented to occur in calcareous substrates, in fellfield cushion plant communities of the alpine of Wyoming and Montana, including Madison Limestone (Lesica and Antibus 1986). *Eritrichum nanum* var. *aretioides* was found to be infected with vesicular-arbuscular mycorrhizal root infection at four of six study sites (Lesica and Antibus

1986). While *E. howardii* is not strictly an alpine plant, the harsh windswept ridges it inhabits mimic alpine conditions. It is probable that vesicular-arbuscular mycorrhizal root infection occurs in *E. howardii* occurrences. Regardless of the lack of information concerning any specific mycorrhizal association that *E. howardii* may have, this species may ultimately benefit from the mycorrhizal relationships that other members of the habitat may contribute to the substrate.

Demography

Not enough is known about the habitat, autecology, reproduction, or population dynamics of *Eritrichum howardii* to determine a primary cause for its rarity. It is likely due to the rarity and isolation of the calcareous substrates with which *E. howardii* is associated.

The life history of *Eritrichum howardii* remains uninvestigated. Hitchcock (1959) indicated that it is a long-lived plant. No demographic studies have been initiated or accomplished to determine time to reproductive maturity, net reproductive rate, or age distribution of *E. howardii*. No information concerning recruitment, survival, or lifespan has been documented. Estimates of the proportion of populations that are reproducing are not available. Occurrence data from WYNDD reports and herbarium specimens indicate whether populations were flowering and fruiting at the time of collection, suggesting that at least some plants in the occurrence were reproducing. However, there are no reports of seedlings. Even if the plants are flowering and fruiting, it is not possible to know if effective reproduction is occurring.

A demographic projection matrix provides valuable information about the vital rates of a species, and it is determined by tracking the fate of individuals over time. There are no established demographic monitoring sites for *Eritrichum howardii*. No data exist for constructing a population projection matrix or a life cycle diagram as per Caswell (2001). A working plan for a lifecycle diagram is presented in **Figure 7**. It is not known whether an immature stage exists. If there is a juvenile stage, it is unknown whether juveniles must attain a certain size or age before becoming reproductive nor is it known if reproductive adults revert to a vegetative state. Seed bank dynamics (e.g., germination rates, seed longevity, abundance) are unknown but are represented in the diagram by a question mark between seed bank and seed. No information is available on seedling survival, depicted in the diagram by a question mark between seed and seedling.

A population viability analysis (PVA) is a rigorous quantitative analysis using demographic data to predict the future status of a species. An analysis predicting the minimum population necessary (minimum viable population, also known as MVP) to have an acceptably low extinction probability would be useful information for management purposes. It has been suggested that demographic data are of more immediate importance then genetics in determining the MVP of a plant population (Landes 1988, Menges 1991). Menges (1991) also suggested that if a plant population is able to buffer environmental stochasticity, then it is sufficient to protect the genetic integrity of plant populations. No PVA has been accomplished or MVP determined for *Eritrichum howardii*.

Few factors limiting the population growth of *Eritrichum howardii* have been identified; possible factors include low germination, low seedling survivorship, and the inability of the species to disperse or compete with dense vegetation. Predation has not been investigated nor has grazing pressure been reported at any of the known occurrences. Currently, no empirical data exist examining other factors such as seed predation, competition, habitat destruction or fragmentation, or any other factor limiting population growth.

Community ecology

The influence of habitat and disturbance regime on community structure in the alpine and the montane zones has been studied in depth (Billings 1988, Peet 1988). *Eritrichum howardii* apparently prefers open, exposed, sparsely vegetated sites. These sites are often maintained through climatic factors such as wind, sun exposure, and dry gravelly calcareous soils. It is not known how *E. howardii* habitat sites were established.

Eritrichum howardii habitat sites are more or less stable areas, albeit harsh. In the absence of anthropogenic related activities, these habitats tend to remain stable. As a stress-tolerant species, *E. howardii* would likely not successfully establish itself in microhabitats where a competitive ability is essential to survival. Plants adapted to harsh environments, including those species with specific soil requirements, are often poor competitors (Grime 1979).

Eritrichum howardii's preference for harsh, wind-swept environments may provide a degree of isolation from interactions with invasive as well as competitive native species. No invasive species have been reported

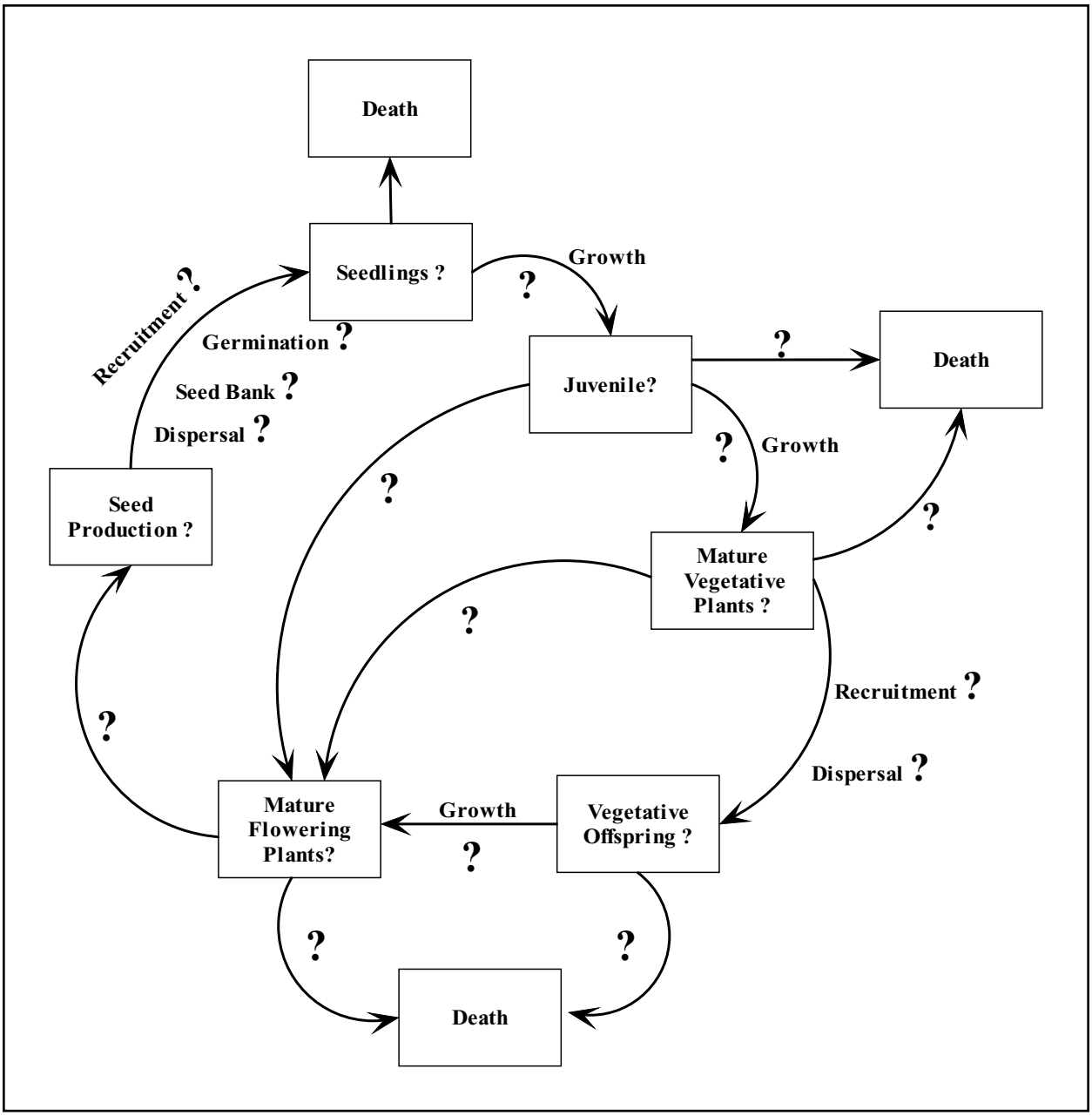

Figure 7. Generalized life cycle diagram for *Eritrichum howardii*. Question marks indicate uncertainty during a particular stage or a lack of understanding of the mechanisms between stages.

within known occurrences of *E. howardii*; however, increased competition may have a negative effect on the ability of *E. howardii* to persist in its preferred habitat. It is unknown whether interactions with native species have any effect on the distribution or abundance of *E. howardii*. There have been no recorded observations of interactions between *E. howardii* and herbivores.

There are no studies investigating parasites or diseases that may affect *Eritrichum howardii*, nor have there been any investigations of symbiotic or mutualistic interactions. Entomophily (pollination by insects) is an important symbiotic relationship for most flowering plants. *Eritrichum howardii* probably depends on insects to effect pollination. Specific data concerning interactions among *E. howardii* and insects are unavailable. The Biology and Ecology section contains a general discussion of entomophily and the Boraginaceae.

An envirogram is a useful tool for evaluating the relationship between the environment and a single

species. It traces the environmental factors that affect a species from the most indirect (distal) interactions to factors that have a direct (proximal) effect (Andrewartha and Birch 1984). The envirogram is a series of webs that converge upon a centrum. The centrum consists of the basic components of environment that cause an increase, decrease, or no change in the expectation of fecundity and survivorship of a species. It is the most proximal level of the envirogram, and directly affects the target species (Andrewartha and Birch 1984). For plants, the centrum consists of resources (light, soil moisture, and nutrients), reproduction (flowering/ fruiting, growth and development, and seedling establishment), and malentities (human interactions, extreme weather, and herbivory).

The envirogram is constructed as a modified dendrogram, with the centrum placed at the most proximal level to the species. From each of the centrum components, a web is constructed distally, illustrating factors that affect the centrum component, termed Web 1. Web 2 consists of factors that affect Web 1, Web 3 consists of factors that affect Web 2, and so on. One of the primary functions of an envirogram is to identify areas of research and propose hypotheses (Andrewartha and Birch 1984). As with all analytical tools, the best envirogram is based on a complete data set. Despite the lack of ecological and environmental data for *Eritrichum howardii*, an envirogram was constructed for this species (**Figure 8**, **Figure 9**, **Figure 10**). Entries with a question mark denote areas in need of further research, such as pollination mechanisms, flowering/ fruiting, the effect of disturbance, herbivory, and dispersal vectors.

The resources centrum for *Eritrichum howardii* (**Figure 8**) is made up three proximal factors: soil moisture, light, and nutrients. Soil moisture is affected by precipitation, soil permeability, soil water retention, and runoff. Light can be affected by community structure and topographic position. The nutrient centrum is affected by substrate parent material and organic materials in the soil. The reproduction centrum (**Figure 9**) consists of factors affecting flowering and fruiting (pollination, weather, dispersal), seedling establishment (safe sites, substrate), and growth and development (weather, light, substrate). The malentities centrum (**Figure 10**) identifies factors that may negatively affect *E. howardii*. These include such things as extreme weather conditions, herbivory, competition, disturbance, air pollution, and global climate change. Malentities are discussed in detail in the Threats section. To aid viewing, each centrum is color coded. The resources centrum is green, the reproduction centrum is yellow, and the malentities centrum is blue.

CONSERVATION

Threats

Current threats to *Eritrichum howardii* are difficult to identify due to the remoteness of occurrences and lack of information. Concern for the viability of the species on National Forest System land within Region 2 reflects its limited abundance and restricted distribution on the periphery of the species' range. The sizes of populations on National Forest System land within Region 2 are small or are unknown. The species occupies specialized microsites defined by sparse vegetation and calcareous soils.

The majority of the information in this section is based on the assumption that most montane foothill areas are subject to a range of general threats. These include ORV recreation, road development, impacts of hikers and pack animals, grazing, and fire. A potential residential development has been identified as a specific threat in the lower foothills of the Heart Mountain area. However, The Nature Conservancy acquired the property at Heart Mountain Ranch in 1999. Other potential threats to the species include air pollution (i.e., acid rain, nitrogen deposition), extreme weather conditions, and global warming.

The remote location of known occurrences provides some degree of protection; however, land managers need to be made aware of the location of occurrences in order to make informed management decisions and avoid damaging occurrences unintentionally.

Recreation

Recreation use in the proximity of occurrences located on the Shoshone and Bighorn national forests consists primarily of ORVs, hiking, and horseback riding. Although ORV use occurs on both the Bighorn and Shoshone national forests, no use was reported in the vicinity of *Eritrichum howardii* occurrences. No information is available to determine the extent of impacts to the species from recreation. However, as recreational use of the Bighorn and Shoshone national forests increases, the potential threat to individuals or occurrences increases. Recreation conflicts with rare plant species may include trampling within occurrences, collecting of flowers or seeds, and habitat degradation (Hamilton and Lassoie 1986).

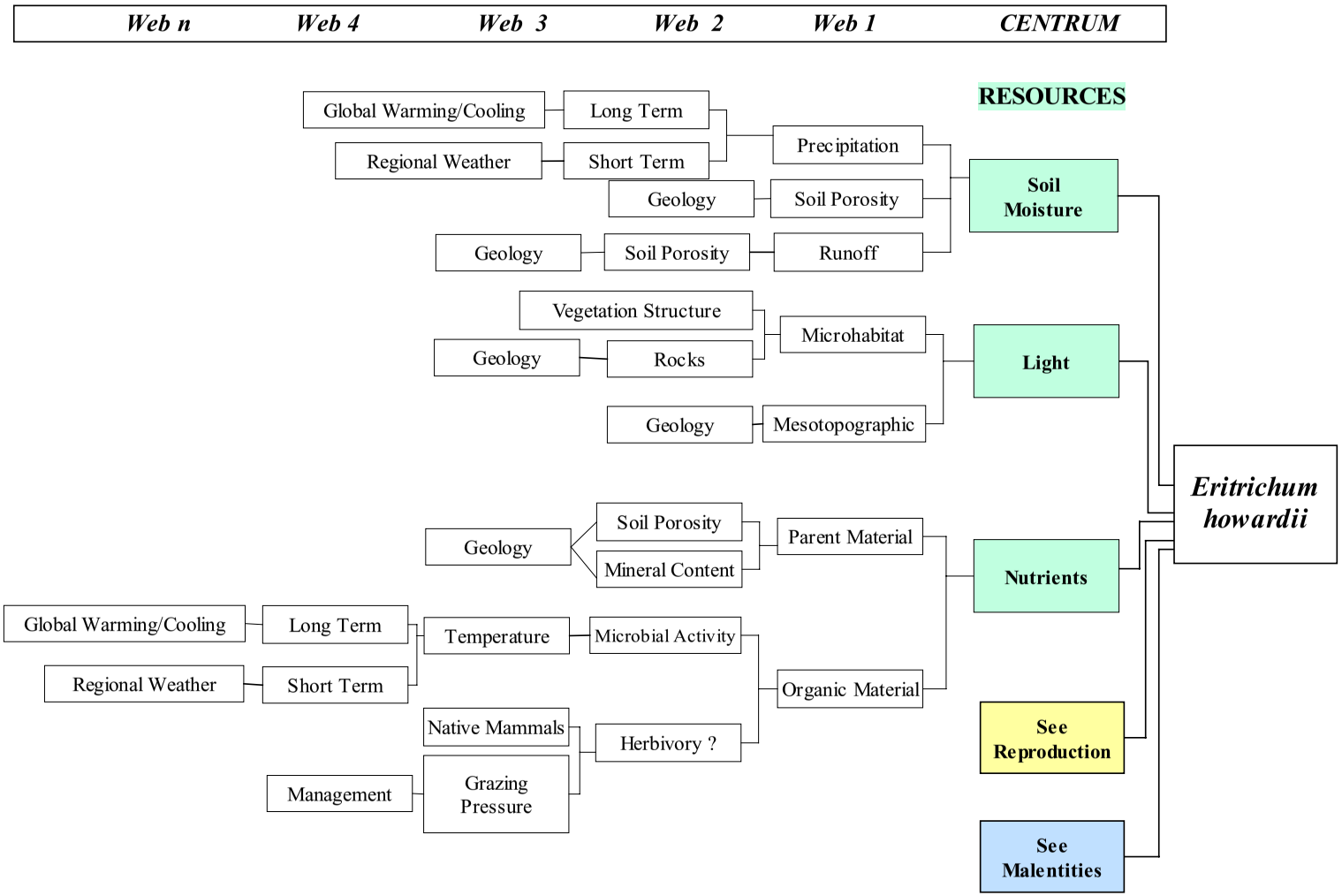

Figure 8. Resources centrum for *Eritrichum howardii* envirogram. Green boxes indicate resources, yellow indicates reproductive, and blue indicates malentities.

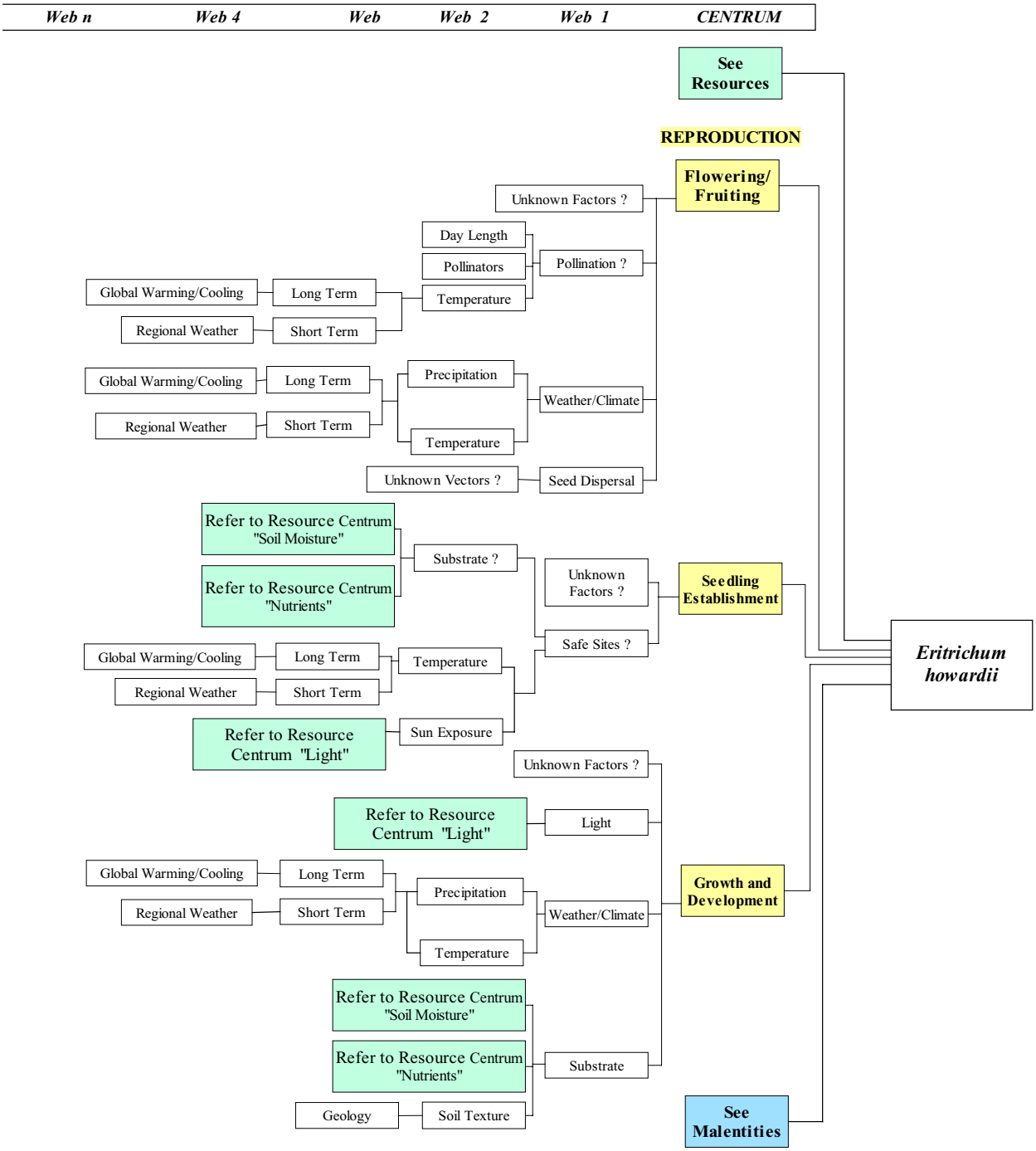

Figure 9. Reproduction centrum for *Eritrichum howardii* envirogram. Green boxes indicate resources, yellow indicates reproductive, and blue indicates malentities.

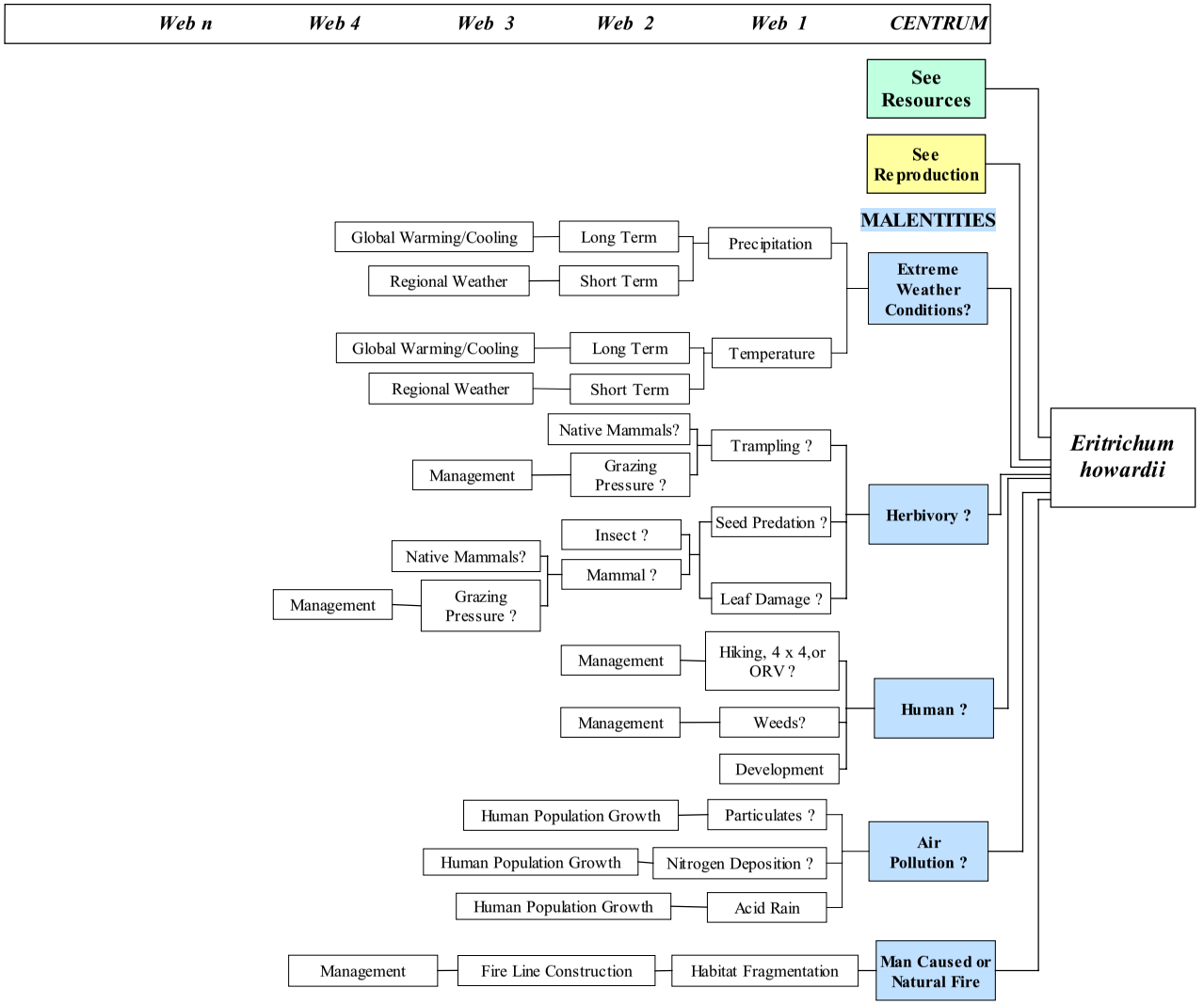

Figure 10. Malentities centrum for *Eritrichum howardii* envirogram. Green boxes indicate resources, yellow indicates reproductive, and blue indicates malentities.

Fire

Eritrichum howardii is a plant of montane, foothills, and occasionally subalpine habitats with sparse vegetation and little shade. While these habitats may be at limited risk of fire because of a lack of fuel, fire line access and construction could affect individuals or occurrences through trampling, destruction of individual plants, or habitat fragmentation. In fact, the degree of threat posed by fire line access and construction could be higher than the threat of the fire itself. Habitat fragmentation may create metapopulations or reduce genetic diversity among small populations. No information was identified that suggested that a recurring fire regime is necessary to maintain *E. howardii* occurrences.

The effects of fire on vegetation are difficult to quantify, as they vary with burn intensity and are spatially heterogeneous (Brown and Smith 2000). Little information is available to determine the degree of threat posed by natural or prescribed fire. A bibliography of the effects of fire on threatened and endangered species can be found in Hessl and Spackman (1995) and effects on plant species in general can be found in a publication concerning wildland fire in ecosystems and effects of fire on flora (Brown and Smith 2000). No references were identified in these publications specifically concerning *Eritrichum howardii*.

Grazing

Impacts from grazing have not been observed nor investigated for this species at any of the known locations on the Bighorn or Shoshone national forests. Livestock use of *Eritrichum howardii* habitat would presumably be low, based on the lack of palatable forage within the species' habitat. Secondary impacts from grazing include changes in plant species composition (including the spread of invasives), soil compaction, and erosion, all of which have the potential to impact *E. howardii*. In general, the isolation from water sources and location in sparsely vegetated habitats suggest that the direct threat of grazing to *E. howardii* is minimal.

Other threats

Road development and ORV travel have been identified as potential threats to individual plants of *Eritrichum howardii* (USDA Forest Service 2003a). Potential threats to the species as a whole include global warming, extreme weather events, and air pollution, including acid deposition. However, the calcareous substrates on which this species is found may buffer the impacts from acid deposition.

Global warming has been identified as a potential threat to both forested and non-forested communities. In Wyoming, potential impacts to forested communities as a result of global warming include alteration of species composition, geographic range, health and productivity (U.S. Environmental Protection Agency 1998). Global warming could cause severe drought or otherwise modify climate regimes, thus affecting the survivorship of individual plants or their ability to reproduce. Unusually cold springs may delay reproduction and seed set of *Eritrichum howardii*.

Soils and vegetation in Yellowstone National Park may be sensitive to nutrient enrichment from nitrogen deposition. In some parts of the United States, including some high-elevation ecosystems in the Rocky Mountains, nitrogen deposition has altered soil nutrient cycling and vegetation species composition; invasive species that are able to take advantage of increased nitrogen levels have replaced native plants that evolved under nitrogen-poor conditions (National Park Service 2006). Possible effects of nitrogen deposition on terrestrial ecosystems include premature abscission of pine needles, alteration of mycorrhizal fungi, loss of lichen communities, enhancement of non-native species invasions, and alteration of fire cycles by increasing fuel loads (Fenn et al. 2003). A study of nutrient availability, plant abundance, and species diversity in alpine tundra communities determined that addition of nitrogen resulted in an increase in species diversity in a dry meadow (Theodose and Bowman 1997).

Conservation Status of Eritrichum howardii in Region 2

The distribution and autecology of *Eritrichum howardii* are poorly understood, and it is difficult to ascertain the viability of this taxon with so little information. The known distribution in Wyoming is limited and may be related to the lack of inventory. Abundance data do not exist for any occurrences throughout its range. Demographic parameters, population structure, and ecological strategies are all biological aspects of *E. howardii* that remain uninvestigated at this time. One of the eight occurrences in Wyoming (WY #001 in **Table 2**) has a low likelihood of being relocated because locality information is lacking. One occurrence (WY#008 in **Table 2**) is protected by the Nature Conservancy at Heart Mountain Ranch. Rigorous estimates or censuses of

plant abundance could be obtained from the remaining seven locations in Wyoming.

Occurrences of *Eritrichum howardii* may be at risk from environmental stochasticity or natural catastrophes based on the size of populations. A minimum viable population small size has not been determined for this species. A very rough estimate of the total population in Region 2, based on available data and communications with knowledgeable botanists, is at least several hundred individuals. This number becomes significant when one considers that 500 individuals is suggested as a minimum population size sufficient to maintain genetic variation for adaptation to a changing environment (Lande 1988, Frankel and Soule 1981). *Eritrichum howardii* may be close to this minimum number. In addition, the effective population size in Wyoming may be less than 500. The Wyoming locations are widely spaced; there is likely little or no genetic connectivity among occurrences. Factors increasing the risk of the species succumbing to environmental stochasticity include geographically isolated populations and limited dispersal capability. Seedling recruitment may be a factor limiting population growth, particularly in the sparsely vegetated dry foothills. No information was identified that indicated that any occurrences on National Forest System lands within Region 2 have declined or disappeared because of environmental stochasticity or land management practices.

Potential Management of Eritrichum howardii in Region 2

Implications and potential conservation elements

Detailed biological and ecological studies of *Eritrichum howardii* and associated habitat have not been conducted. In order to conserve occurrences and habitat, managers need additional information describing the distribution, biology, and ecology of the species. Surveys for new occurrences, counting plants in known sites, studying reproductive factors, describing life history stages, population structure, longevity, and mortality, and determining the effects of management activities and natural disturbances would provide land managers with the tools they need to make good decisions regarding this species.

Tools and practices

As mentioned in the Habitat section, *Eritrichum howardii* appears to be restricted to sparsely vegetated areas mostly associated with calcareous soils. Additional occurrences are possible in Region 2. Targeted searches of potential habitat will be most effective when flowers are present (i.e., June through July) and will provide additional information concerning the distribution of the species.

Documented habitat descriptions consistently note that this species occurs on coarse soils composed of large cobbles and/or gravels derived from calcareous parent materials. Because Wyoming botanists are particularly interested in calcareous habitats, many of the easily accessible limestone and dolomite substrates have been surveyed. Nevertheless, it is likely that more of this type of habitat remains to be searched. Because calcareous outcrops are uncommon, it is unlikely that large numbers of undiscovered *Eritrichum howardii* occurrences exist in Wyoming. The Bighorn Mountains, particularly the western slope and the northern and southern foothills, contain a significant amount of calcareous substrates and may provide potential habitat for *E. howardii*. Other potential habitat may exist in the eastern Absaroka Mountains and the Beartooth Mountains. Fertig and Thurston (2003) modeled potential distribution of *Shoshonea pulvinata* utilizing geology and elevation models. *Eritrichum howardii* has been known to occur with *S. pulvinata*. Surveys for both species could be conducted concurrently.

At a minimum, visiting known occurrences every few years and making estimates of the number of plants present constitutes the most economical methodology to document general trends in population and to identify visible impacts to occurrences. However, population estimates alone do not provide information about the reproductive biology or population dynamics of *Eritrichum howardii*. Rigorous population or demographic monitoring studies are needed to ascertain parameters of the species' life history, including generation time, net reproductive rate, age distribution, and potential reproductive output lost to abortion and predation (Elzinga et al. 1998).

Protecting occurrences is necessary for maintaining the viability of *Eritrichum howardii* on National Forest System land in Region 2. Although *E. howardii* is not considered a sensitive species in Region 2, the National Forest Management Act of 1976 requires the USFS to sustain habitats that support healthy populations of existing plant and animal species on the national forests and grasslands. Site-specific inventories conducted prior to initiating management activities and evaluations of impacts to *E. howardii* could minimize

negative effects of management. Establishing special management areas for the species would also help to ensure the species' persistence.

Any new data describing the plant composition, structure and function of the community would provide a baseline and clues as to possible limiting factors controlling the distribution of the species. Common variables to be measured include cover or density parameters of important plant species, soil surface conditions, and microhabitat observations, including slope, aspect, and geologic substrate. Periodic habitat monitoring could be conducted simultaneously with collection of population estimates and would provide a basis document calculate rates and types of change that can occur in response to natural process such as succession and disturbance. Establishment of permanent photo points would provide a simple and economical method to monitor overall change at the microsites where *Eritrichum howardii* occurs (Elzinga et al. 1998). Permanent photo points, periodic population counts, and habitat monitoring would show if management objectives need to be modified to protect the species.

The mission of the Center for Plant Conservation is to conserve and restore the rare native plants of the United States. No plant material for *Eritrichum howardii* has been stored by the Center for Plant Conservation (Center for Plant Conservation 2006).

Information Needs

Continued efforts to locate new occurrences by the use of presence/absence surveys may provide additional information concerning the distribution of *Eritrichum howardii*. This information will assist in the formulation of conservation strategies to protect occurrences on National Forest System lands within Region 2.

Additional recommendations for further study include:

- initiate field surveys to relocate historic locations
- initiate monitoring studies of known locations
- search regional herbaria for misidentified specimens that could increase the number of occurrences.
- evaluate the reproductive and ecological characteristics of the species, including pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting, and dispersal vectors
- address population viability questions (i.e., vital rates, recruitment, survival, reproductive age, lifespan, proportion of populations reproducing, seed viability, seed bank dynamics, longevity) through demographic studies.

DEFINITIONS

Corona – Petal-like or crown-like structures between the petals and stamens in some flowers (Harris and Harris 1994).

Cymose – Inflorescence composed of a flat-topped or round-topped determinate inflorescence, paniculate, in which the terminal flower blooms first (Harris and Harris 1994).

Entomophily – Pollination by or dispersed by the agent of insects (Lincoln et al. 1982).

Environmental stochasticity – Variation over time in the populations operational environment (Menges 1991).

Generation time – The mean period of time between reproduction of the parent generation and reproduction of the first filial generation (Lincoln et al. 1982).

Hermaphrodite – With pistils and stamens in the same flower (Harris and Harris 1994).

Heterozygosity – Having two different alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Homozygosity – Having identical alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Inbreeding – Mating or crossing of individuals more closely related than average pairs in the population (Lincoln et al. 1982).

Inbreeding depression – Reduction of fitness and vigor by increased homozygosity as a result of inbreeding in a normally outbreeding population (Lincoln et al. 1982).

Longevity – The average life span of the individuals of a population under a given set of conditions (Lincoln et al. 1982).

Outcrossing – Mating or crossing of individuals that are either less closely related than average pairs in the population, or from different populations (Lincoln et al. 1982).

Salverform – With a slender tube and an abruptly spreading, flattened limb (Harris and Harris 1994).

Self-compatible – Used of a plant that can self-fertilize (Lincoln et al. 1982).

Selfing – Self-fertilizing or self pollinating (Lincoln et al. 1982).

Vesicular-arbuscular mycorrhizal – A mutualistic symbiotic relationship in which individual hyphae extending from the mycelium of a fungus colonize the cortical cells of the roots of a vascular plant.

Vestiture – Referring to hair characteristics of the plant pubescence.

Vital rates – Annual rates of survival, growth, and fecundity (Morris et al. 1999).

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